

ROCK SHAFT RESISTANCE OF BORED PILES SOCKETED INTO  
DECOMPOSED MALAYSIA GRANITE

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*I dedicate this project report to*

*All my family, the symbol of love and giving,*

*My friends who encourage and support me,*

*All the people in my life who touch my heart,*

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## ABSTRACT

The design of large diameter bored piles socketed into rock has emphasized considerable attention in sedimentary rocks. However, the design only has been occasionally addressed in igneous and metamorphic rocks. Design methods based on the performance of sockets in sedimentary rocks have been proposed in literature, but it is uncertain how applicable they are to other rock types. This paper attempts to review the applicability of the formulae published in the literature in granite formation of Malaysia. A program of field testing tests was conducted to measure the axial response of bored piles. A total of 15 bored piles of diameter varying from 1000mm to 1500mm were constructed in decomposed granite using techniques including advancing of temporary casing and with drilling slurry composed of bentonite fluids. These bored piles were tested with static load test and high strain load dynamic test to verify its integrity and performance and the results of the load tests were evaluated in this study. The results demonstrate that method proposed by Horvath & Kenny gives the best prediction of rock shaft resistance for decomposed granite. The trend of the rock discontinuities were also scattered with relationship to rock shaft resistance and rock compressive strength although proportional increase of rock compressive strength with rock quality designation was observed. Based on the results obtained and the assessment made in this study, it can be deduced that the proposed literature based on sedimentary rocks is applicable to decomposed granite and the maximum rock shaft resistance can mobilise up to 1850kPa in RQD>60%.

## ABSTRAK

Reka bentuk cerucuk tuang situ bersaiz besar yang disoket ke dalam batu telah banyak memberi perhatian dalam jenis batuan sedimen. Walau bagaimanapun, hanya kadang-kadang sahaja reka bentuk di dalam batuan igneus dan metamorfik diketengahkan. Kaedah reka bentuk berdasarkan prestasi soket dalam batuan sedimen telah dicadangkan dalam banyak penulisan, tetapi tidak pasti bagaimana aplikasi kaedah tersebut boleh dipakai kepada jenis batuan yang lain. Kertas kerja ini cuba untuk mengkaji kebolegunaan rumus yang diterbitkan dalam penulisan sebelumnya untuk jenis batuan granit di Malaysia. Program ujian lapangan telah dijalankan untuk mengukur tindak balas paksi cerucuk tuang situ. Sebanyak 15 cerucuk tuang situ berlainan diameter dari 1000mm 1500mm telah dibina di dalam granit terluluhawa menggunakan teknik termasuk memasukkan selongsong sementara dan dengan penggerudian lumpur yang terdiri daripada cecair bentonit. Cerucuk tuang situ ini telah diuji dengan ujian beban statik dan ujian beban ujian dinamik untuk mengesahkan integriti serta prestasi dan keputusan ujian beban telah dinilai dalam kajian ini. Keputusan menunjukkan bahawa kaedah yang dicadangkan oleh Horvath & Kenny memberikan ramalan yang terbaik bagi ketahanan sisi batu granit terluluhawa. Trend bagi ketidakselajaran batu juga berselerak dengan hubungan ketahanan sisi batu dan kekuatan mampatan batu walaupun peningkatan berkadar pada batu kekuatan mampatan dengan penetapan kualiti batu (RQD) diperhatikan. Berdasarkan keputusan yang diperolehi dan penilaian yang dibuat dalam kajian ini, dapat disimpulkan bahawa penulisan yang berasaskan batuan sedimen adalah boleh dipakai untuk granit terluluhawa dan maksimum ketahanan sisi batu boleh mencecah sehingga 1850kPa dalam  $RQD > 60\%$ .

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## LIST OF SYMBOLS

$Q_{ag}$	-	Allowable geotechnical capacity
$Q_{su}$	-	Ultimate shaft capacity
$Q_{bu}$	-	Ultimate base capacity
$f_{su}$	-	Unit shaft resistance for each layer
$f_{bu}$	-	Unit base resistance for the bearing layer
$A_s$	-	Pile shaft area
$A_b$	-	Pile base area
$F_s$	-	Partial Factor of Safety for Shaft Resistance
$F_b$	-	Partial Factor of Safety for Base Resistance
$F_g$	-	Global Factor of Safety for Total Resistance
$K_{su}$	-	Ultimate unit shaft resistance of soil
$K_{bu}$	-	Ultimate unit bearing resistance of soil
$\alpha$	-	Adhesion factor
$s_u$	-	Undrained shear strength
$K_{se}$	-	Effective stress shaft resistance factor
$\sigma_v$	-	Vertical effective stress
$\phi'$	-	Effective angle of friction (degree) of soils
$N_c$	-	Bearing capacity factor
$\beta$	-	Shaft resistance factor for coarse grained soils
$q_{uc}$	-	Unconfined compressive strength of intact rock
$\alpha$	-	Reduction factor with respect to $q_{uc}$
$\beta$	-	Reduction factor with respect to the rock mass effect
$q_s$	-	Ultimate rock shaft resistance

$\sigma_{uc}$	-	Unconfined compressive strength of intact rock
$\sigma_{rc}$	-	Unconfined compressive strength of rock or concrete
$j_c$	-	Case method damping factor
$\varepsilon$	-	Strain
$R_u$	-	Ultimate resistance in the soil ‘springs’
$q_{s(max)}$	-	Maximum mobilised rock shaft resistance

## **CHAPTER 1**

### **INTRODUCTION**

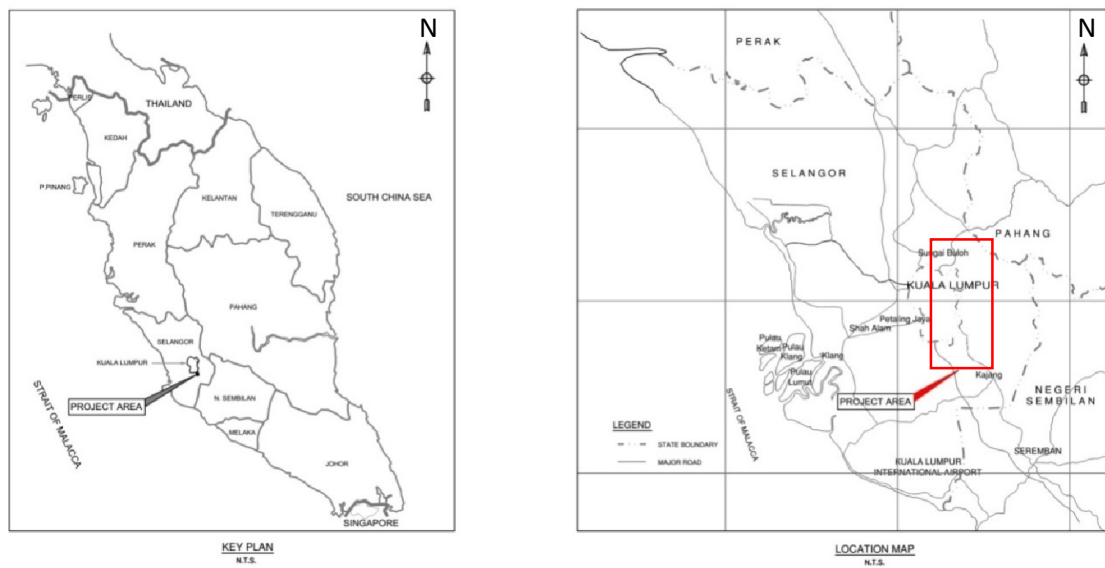
#### **1.1 Background**

The Klang Valley Mass Rapid Transit (KVMRT) is the latest rail-based public transport development and being constructed by Government of Malaysia to alleviate the traffic congestion in Kuala Lumpur. This first phase of this project involves the construction of 51km rail alignment from Sungai Buloh to Kajang. Locations of the KVMRT project are shown in Figure 1.1 and Figure 1.2. As initially envisaged the project required the construction of thousands of large diameter bored piles from 1m diameter and up to 2.8m diameter to support both the viaducts and station developments. These structures were to be founded on a wide range of rock types comprising the geological of granite, kenny hill, limestone and kajang formations.

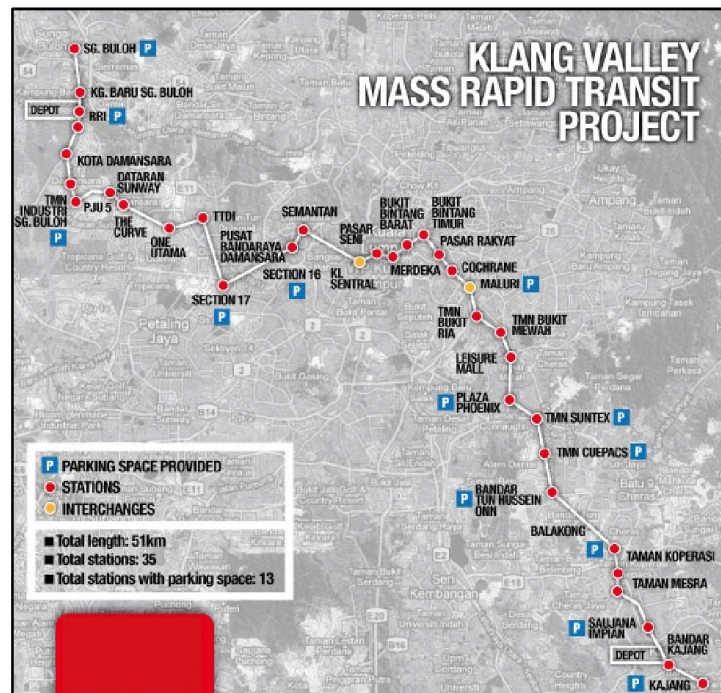
Deep foundations are a common foundation selection for all types of structures particularly cast in-situ bored pile. Bored pile was chosen in the advantages of minimum ground vibration, higher design working load, and can be installed into rock bearing strata. It is becoming common practice to socket the shafts into bedrock to transmit high foundation loads. However, the need to improve the



efficiency of pile designs and higher design loads is providing an increasing requirement for rock-socketed piles. Design loads are limited for piles relying upon end bearing in rock, even if the measured rock strength is higher than the pile concrete strength. This is due to uncertainty about the rock quality over whole pile diameter, which may be lower than expected because of weathering or construction effects. Thus, it is prudent to design an optimum rock shaft resistance in order to prevent excessive rock socketing.



**Figure 1.1 : Key Plan and Location Map**



**Figure 1.2 : Proposed MRT Alignment (Sungai Buloh to Kajang)**

Due to the uncertainties associated with pile design, available semi-empirical/empirical methods for determination of ultimate resistance of pile may pose unreliability and, thereby, may significantly affect safety and economy of a project. Therefore, although expensive, pile load tests are usually conducted to verify the design loads and to evaluate the actual response of the pile under loading.

Static load tests (SLT) are generally a “must” and are among the most reliable and important to ensure satisfactory pile performance with particular reference to the capacity, settlement and structural integrity. Usually, at least one or two tests per site or 1 to 2% of the piles are selected for load tests. During this test, load would be applied on the selected pile and the pile settlement under the acting load would be recorded. As a common practice, pile would be loaded up to twice of the working load, which is regarded as the Test Load of the pile. On most occasions, the results of this test do not show a distinct plunging ultimate load, therefore the results need interpretation to estimate pile capacity or ultimate load.

## **1.2 Problem Statement**

It is noticeable that very few studies on the ultimate rock shaft resistance of bored piles particularly on igneous rock have been carried out in Malaysia. Most of the bored piles design Malaysia is practised in based on the proposed literatures which were emphasized on sedimentary rocks. The method used by previous literatures correlates the maximum rock shaft resistance with respect to rock compressive strength which is obtained from laboratory test results conducted on the intact rock core samples.

Design methods based on the performance of sockets in sedimentary rocks have been proposed in the literatures, but it is uncertain how applicable these methods to other rock types. The problem faced by designers is what magnitude of skin friction can be shed into the granite in Malaysia. Whether the characteristics of this type of rock are similar with granite in other countries like Hong Kong.

## **1.3 Objective of the Study**

The aim of this study is to identify the most appropriate interpretation methods to estimate the rock shaft resistance of granite in Malaysia. The objective of the study comprises of the following:

- (i) To review the applicability of available design relationship addressing shaft resistance of decomposed rock.
- (ii) To determine the maximum rock shaft resistance particularly in granite formation in Malaysia.
- (iii) To validate the designs relationship with respect to field pile load test results.

- (iv) To identify the trends in behaviour of rock discontinuities and unconfined compressive strength with respect to maximum rock shaft resistance.

#### **1.4 Scope of the Study**

This study is based on the real time construction project of the proposed Klang Valley MRT Jajaran Sungai Buloh to Kajang. It is worth to note that there are thousands of bored piles have been proposed for foundation supports to the MRT viaducts and station developments. These bored piles are to be founded in wide range of rock types comprised on granite, kenny hill, limestone and kajang formations. However for this study, only the rock shaft resistance of bored piles with diameter varying from 1000mm to 1500mm which were constructed in granite formation have been considered. All of these bored piles were socketed from 1m up to 7.3m into rock and tested with pile load testing.

The scope of this study is on the prediction of socket shaft resistance rather than end bearing resistance. The data for this study was acquired from MMC-Gamuda KVMRT (PDP) Sdn Bhd. These include Soil Investigation Reports, bored piling records and pile load testing results. In total, 15 pile testing results which consists of 5 using static load test and 10 using dynamic load test were reviewed and evaluated.

## **1.5 Significance of the Study**

The precise prediction of maximum rock shaft resistance of bored piles in granite is a complex problem because it is function of a numbers of factors. These factors include method of boring and coring, rock discontinuities, surface roughness, method of concreting, quality of concrete, expertise of the construction personnel, ground conditions etc. beside the pile geometry. Typically, the ultimate values of rock shaft resistance adopted in bored pile design for granite formation in Malaysia is limited between 1000 kPa to 1400 kPa subject to the rock compressive strength results whichever is the lowest.

The significance of this study is to ensure the design methods adopted for design of rock shaft resistance are satisfactory and in order. This study will also provides more understanding on the trends of rock discontinuities particularly of RQD and rock compressive strength with respect to maximum rock shaft resistances. Eventually, magnitude of ultimate rock shaft resistance for granite formation can be determined which can be adopted in the bored pile design.

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